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FILING DATE: *August 20, 2002*
RELATED PCT APPLICATION NUMBER: *PCT/US03/26050*

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08/20/02
Jc887 U.S. PTO

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Jc879 U.S. PTO
60/404694

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Fan-Gang	Zeng	Irvine, CA

☒ *Additional inventors are being named on the 1 separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

POLYMERIC MICRO-CANTILEVER RESONATOR ARRAY AND ITS APPLICATIONS IN AUDITORY PROSTHESES

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 14

☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* (included in spec)

☒ Other (specify) return post card

☒ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☒ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number 50-0878

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($) **$80.00**

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S Government agency and the Government contract number are: ________

Respectfully submitted,

SIGNATURE [signature]

Date 08/20/2002

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Docket Number: UCIVN-021N

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET
Additional Page

PTO/SB/16 (8-00)
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Docket Number	UCIVN-021N	Type a plus sign (+) inside this box ⟶	+

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Number 2 of 2

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Attorney Docket No. UCIVN-021N

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:
Fan-Gang Zeng, et al.

Serial No.: To Be Determined

Filed: Herewith, August 20, 2002

Title: Polymeric Micro-cantilever Resonator Array and its Applications in Auditory Prostheses

Transmittal of Provisional Application for Patent
37 CFR 1.53 (b) (2)

Express Mail Mailing Label No. EV127107105US

Box Provisional Application
Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Enclosed, for filing in the United States Patent Office under 37 CFR 1.53 (b)(2), please find the following documents:

1. Provisional Patent Application consisting of 14 total pages (including Attachments A and B), entitled "Polymeric Micro-cantilever Resonator Array and its Applications in Auditory Prostheses"
2. A completed Provisional Application Cover Sheet consisting of 1 page;
3. Deposit Account Authorization for Small Entity Filing Fee of $80.00; and
4. A Return Postcard

The inventors of the invention(s) disclosed in this Provisional Patent Application are:

Fan-Gang Zeng
Guann-Pyng Li
Mark Bachman
Tao Xu
and
Patrick Coffey

The Notice to File Missing Parts (Filing Date Granted) should be mailed to applicant's undersigned counsel at the address shown herebelow.

Respectfully submitted,

STOUT, UXA, BUYAN & MULLINS, LLP

Date: August 20, 2002

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CERTIFICATE OF MAILING

I hereby certify that this transmittal letter and the accompanying Provisional Patent Application are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR § 1.10 on August 20, 2002 and is addressed to Box Provisional Application, Commissioner for Patents, Washington, D.C. 20231.

Date: August 20, 2002

By: Jean Heuler

Jean Heuler

APPLICATION DATA SHEET

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Application Information

Title Line One:: Polymeric Micro-Cantilever Resonator Array and
Title Line Two:: Its Applications in Auditory Prostheses

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Formal Drawings?::	No
Application Type::	Utility
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Continuity Information

This application is a::
>Application One::
Filing Date::

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State or Province::	
Postal or Zip Code::	

PROVISIONAL APPLICATION FOR UNITED STATES PATENT

by

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Guann-Pyng Li

Mark Bachman

Tao Xu

and

Patrick Coffey

assignors to

The Regents of The University of California

for

Polymeric Micro-cantilever Resonator Array and its Applications in Auditory Prostheses

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DOCKET NO. UCIVN-021N

Express Mail No. EV127107105US

Polymeric Micro-cantilever Resonator Array and its Applications in Auditory Prostheses

Digital signal processing (DSP) technology is presently the main method used by the auditory prostheses because of its frequency analysis ability with flexibility and programmability. The Fast Fourier Transform (FFT) is a common way to perform the sound spectral processing [Hamida, A.B.; Samet, M.; Lakhoua, N.; Drira, M.; Mouine, J., "Sound spectral processing based on fast Fourier transform applied to cochlear implant for the conception of a graphical spectrogram and for the generation of stimulating pulses", Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society, vol.3, pp.1388-1393, Sept. 1998]. The Wavelet Analysis are another common way to perform [Behrenbruch, C.P.; Lithgow, B.J., "SNR improvement, filtering and spectral equalisation in cochlear implants using wavelet techniques", Proceedings of the 2nd International Conference on Bioelectromagnetism, pp.61-62, Feb. 1998]. In addition, the DSP technology is widely applied to digital hearing aid [Mullins, K.A., "Design of a digital hearing aid", IEEE Technical Applications Conference, pp.281-284, Nov. 1996]. The DSP technology employs electrical filters to perform the sound spectral processing, which needs high power consumption and long computation time.

The rapid development of MEMS technology makes silicon cantilever array to be applied in auditory prostheses for the sound spectral processing [M. Harada, N. Ikeuchi, S. Fukui, H. Toshiyoshi, H. Fujita, and S. Ando, "Micro mechanical acoustic sensor toward artificial basilar membrane modeling", Trans. IEE Japan, vol.119-E, no.3, pp.125-130, 1999] and [S. H. Shen, S. T. Young, and W. Fang, "Design and fabrication of a MEMS filter bank for hearing aid aplications", the 2nd Annual International IEEE-EMBS Special Topic Conference on Microtechnologies in Medicine & Biology, pp.352-355, May 2002]. As an inorganic material with high Young's modulus, the silicon material has much different performance from the natural organic material that compose the basilar membrane in human cochlea. Therefore, it can not mimic the function of the basilar membrane very well.

The present invention employs polymeric materials to make the micro-cantilever resonator array, and its application in auditory prostheses. The polymeric micro-cantilever has different performance from the conventional one that employ the material with high Young's modulus, such as silicon. The polymer is similar to the natural organic material, so the polymer micro-cantilever resonator array can mimic the biological front-end processing in the human cochlea very well.

The present invention comprises the design and fabrication of a micro-cantilever resonator array with polymer materials, and its application in auditory prostheses as a biomimetic cochlea that provides a similar function as the basilar membrane in the human cochlea. The micro-cantilever resonator array consists of a series of micro-cantilevers with different resonant frequencies that cover the whole audio frequeny. These micro-cantilevers work as resonators while they serve as polymeric optical waveguides to modulate a light beam. The light from a light source goes through the polymeric cantilever waveguide and enters a detector that is located at the substrate and faces the cantilever with a small gap. When the acoustic wave is introduced to the micro-cantilever resonator array, each frequency component of the wave will excite the resonance of the corresponding cantilever. The detectors will get the modulated light when the cantilever waveguides vibrate. Each cantilever resonance indicates that the same frequency component exists in the acoustic wave while its amplitude indicates the intensity of the frequency component. Therefore, the output spectra of the micro-cantilever resonator array are equivalent as that of frequency analysis with fourier transform or wavelet analysis. Comparing with the digital signal processing (DSP) technology, the micro-cantilever resonator array works as a passive component and with parallel operation mode. Therefore, the micro-cantilever resonator array needs lower power comsumption and shorter processing time. Each frequency channelcan be amplified or attenuated by controlling the intensity of the light for each cantilever.

Attachment A appended hereto further describes and exemplifies the present invention. Attachment B appended hereto is an Abstract & Poster Presentation which further describes and exemplifies the present invention.

Attachment A

1. Device Structure

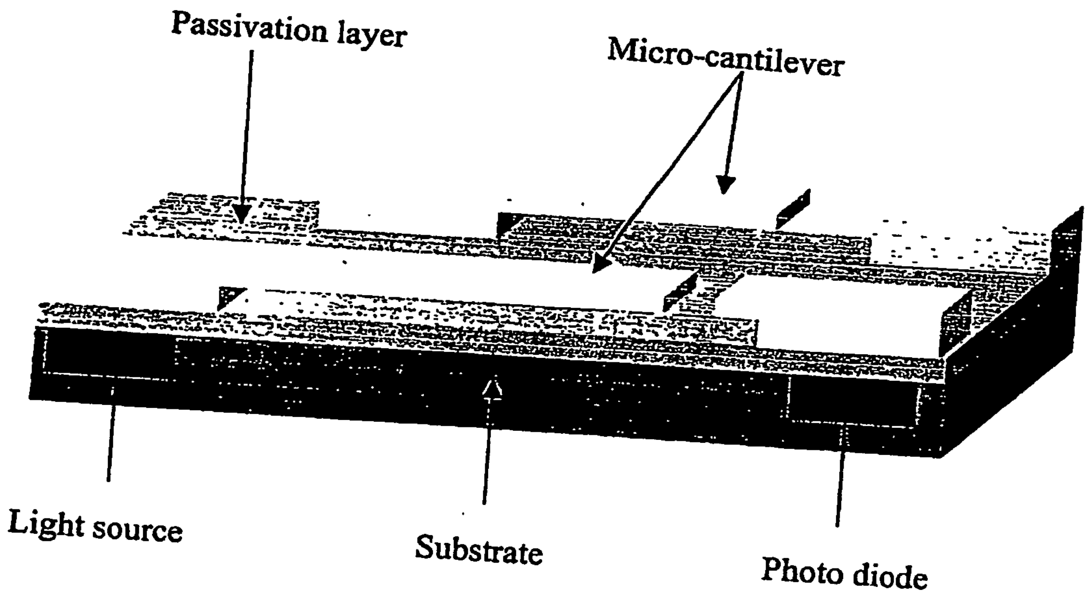
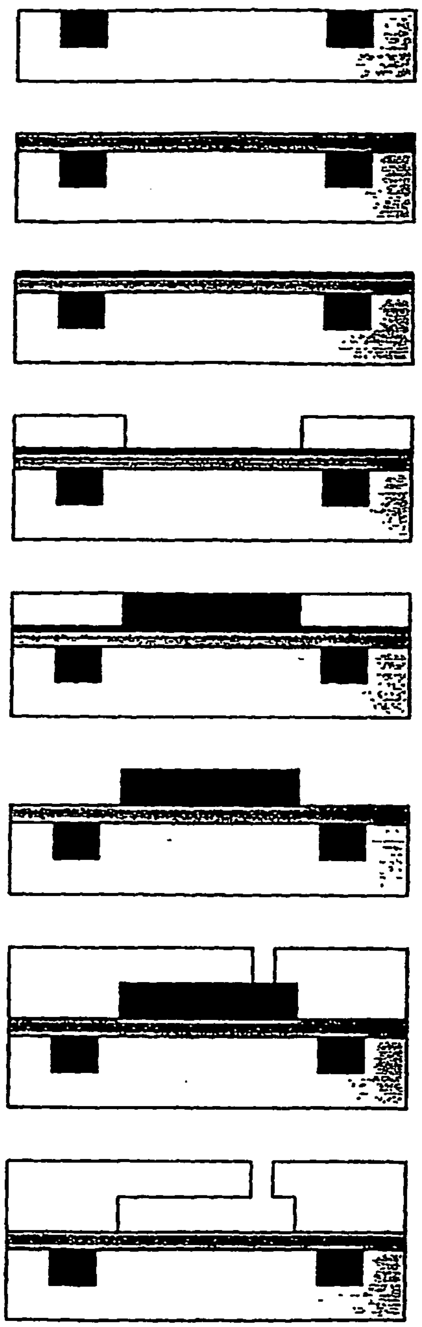


Fig.1 A schematic of the polymeric micro-cantilever resonator array. For simplification, only two cantilevers in the array are drawn.

2. Fabrication Process



Fabricate the LED array and PD array on the substrate with the standard semiconductor process.

Spin a layer of transparent epoxy on the substrate as the passivation layer to protect the LED and PD array.

Deposit 1000A/2500A Ti/Cu seed layer with E-beam evaporator

Spin and pattern 50um SU-8 photoresist with lithography technique.

Electroplate 50um Cu.

Remove the SU-8 photoresist and Ti/Cu seed layer.

Spin and pattern 100um SU-8 photoresist with lithography technique.

Remove Cu to release the cantilever.

Fig. 2 Fabrication process of the polymeric micro-cantilever resonator array. This is a two-masks simple process and compatible with standard semiconductor process.

3. Device Performance

(1) Cantilever 1# with resonant frequency of 286 Hz

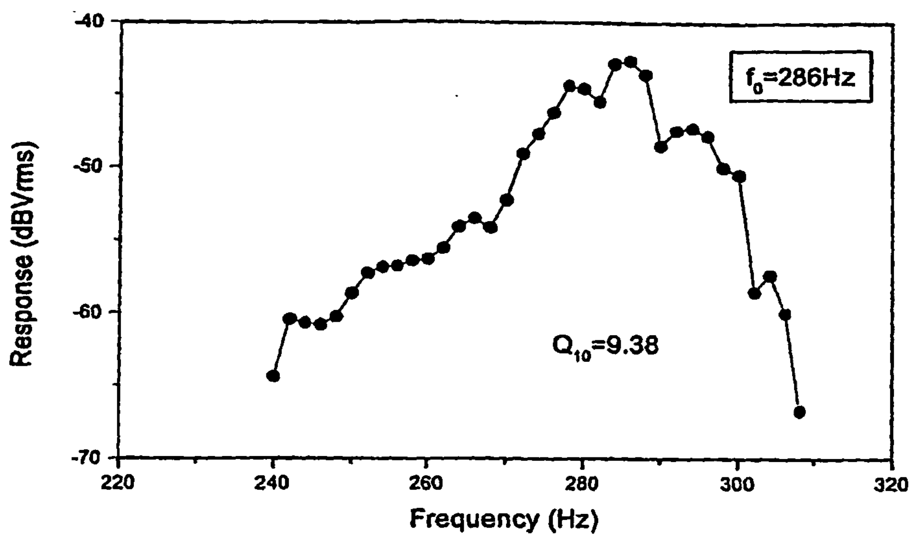


Fig. 3 Frequency response curve of cantilever 1# with resonant frequency of 286 Hz. This curve has the quality factor Q10 = 9.38. The value is similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea.

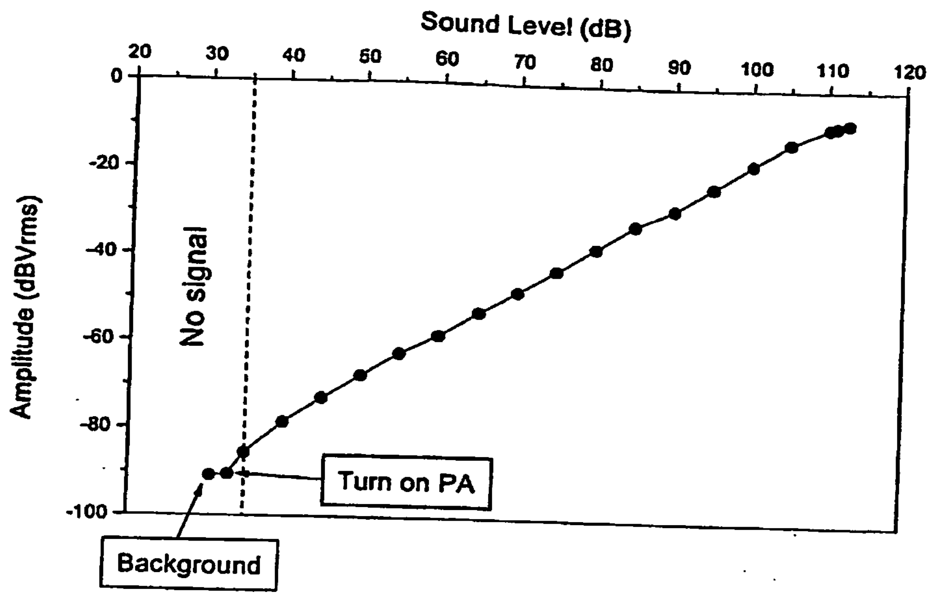


Fig. 4 The amplitude of cantilever 1# at resonant frequency of 286 Hz as a function of input sound level. The cantilever 1# has a linear dynamic range from sound inputs 35 dB SPL to 115 dB SPL.

(2) Cantilever 2# with resonant frequency of 720 Hz

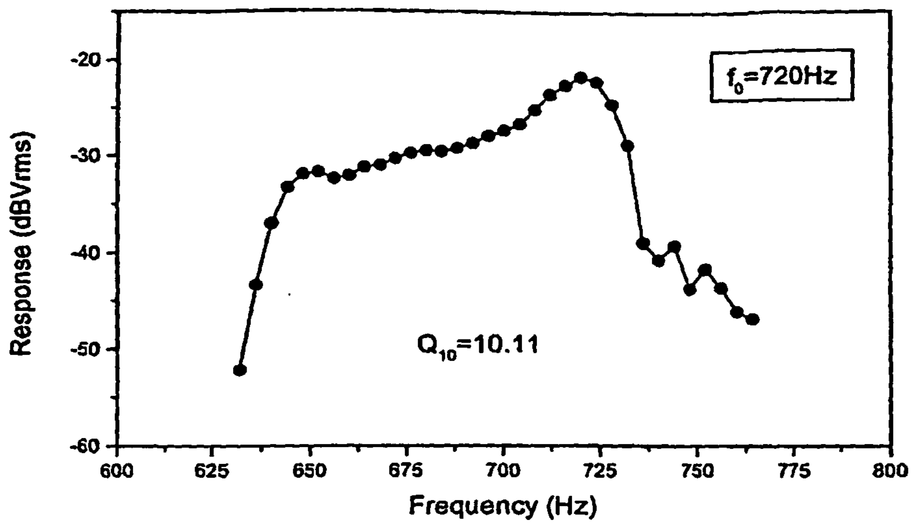


Fig. 5 Frequency response curve of cantilever 2# with resonant frequency of 720 Hz. This curve has the quality factor Q10 = 10.11. The value is similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea.

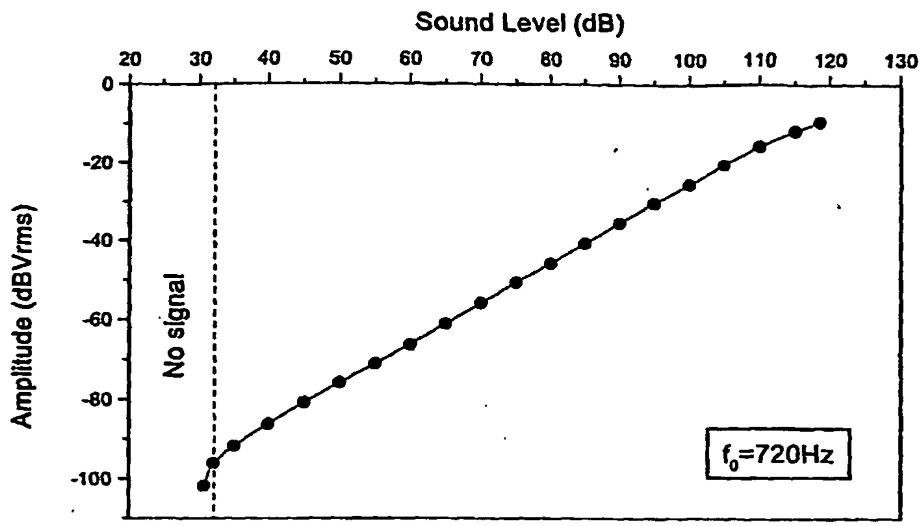


Fig. 6 The amplitude of cantilever 2# at resonant frequency of 720 Hz as a function of input sound level. The cantilever 2# has a linear dynamic range from sound inputs 32 dB SPL to 118 dB SPL.

(3) Cantilever 3# with resonant frequency of 2868 Hz

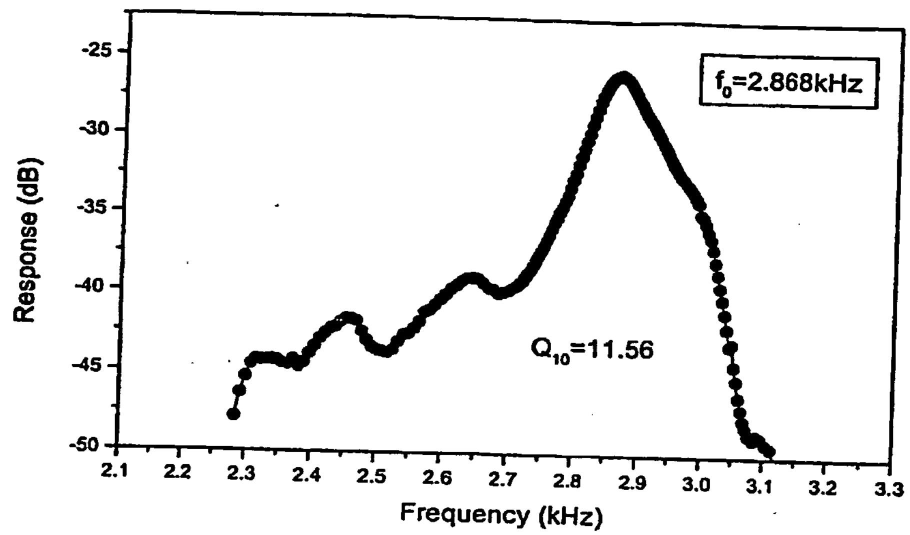


Fig. 7 Frequency response curve of cantilever 3# with resonant frequency of 2868 Hz. This curve has the quality factor Q10 = 11.56. The value is similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea.

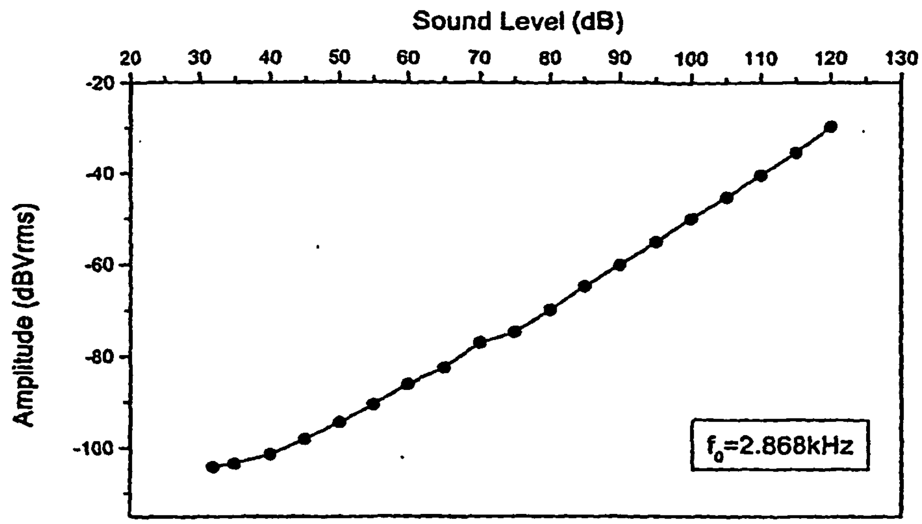


Fig. 8 The amplitude of cantilever 3# at resonant frequency of 2868 Hz as a function of input sound level. The cantilever 3# has a linear dynamic range from sound inputs 30 dB SPL to 120 dB SPL.

(4) Cantilever 4# with resonant frequency of 6948 Hz

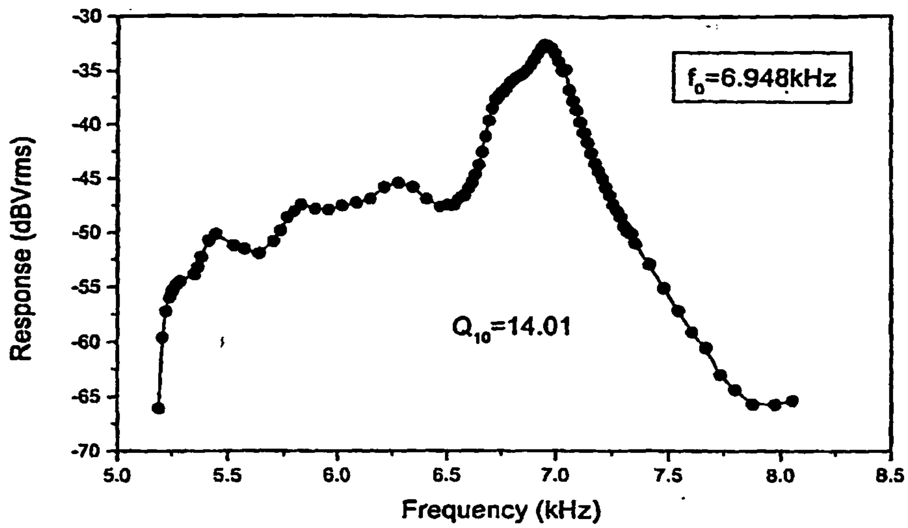


Fig. 9 Frequency response curve of cantilever 4# with resonant frequency of 6948 Hz. This curve has the quality factor Q10 = 14.01. The value is similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea.

ATTACHMENT B

Polymeric micro-cantilever filters for applications in auditory prostheses

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Department of Electrical and Computer Science, University of California, Irvine, CA 92697
* Departments of Otolaryngology and Biomedical Engineering, University of California, Irvine, CA 92697

Ten percent of the general population suffers from hearing loss and that number rises to 35 percent for people over 65 years old. New devices such as digital hearing aids and cochlear implants have significantly improved the quality of life for hearing-impaired people. In these devices, digital signal processing (DSP) is usually used to process the sound for its flexibility and programmability. However, apparent drawbacks in the DSP technique such as high power consumption and long processing time associated with a large number of channels increases its cost and size and limits its utility.

In a mammalian cochlea, filtering, amplification, and compression are achieved by means of mechanical and analog processing. Physiological measures have shown that the organic membranes in the mammalian cochlea have relatively low quality factor (Q10) between 1 and 10 for resonant frequencies in the audio frequency range. These Q10 values are much lower than that of typical mechanical filters made of high Young's modulus materials such as silicon.

Here we propose to use polymeric materials to design mechanical filters that mimic the biological front-end processing in the cochlea. The polymer is similar to the natural organic material and has much lower Young's modulus than the silicon. We use a polymer with 4.4 GPa of Young's modulus to fabricate polymeric micro-cantilever filters that have the Q10 values at 9.38, 10.11, 11.56, and 14.01 for resonant frequencies at 286, 720, 2,868, and 6,948 Hz, respectively. These values are similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea. The polymeric micro-cantilever filters also have a linear dynamic range for sound inputs between 35 and 115 dB SPL. The harmonic distortions are less than 15% throughout most of the dynamic range. The micro-cantilevers fabricated by micromachining process have a dimension ranging from 7.4 x 0.1 x 0.05 mm at low frequencies to 1.5 x 0.1 x 0.05 mm at high frequencies. Because we use an optical method to detect the cantilever's vibration, the final device should have high sensitivity and be free of electromagnetic interference. The polymeric micro-cantilever filters have a great potential for achieving unparalleled real-time processing with high frequency resolution and extremely low power consumption. Their usage in hearing aid and cochlear implant applications should be seriously explored.

POLYMERIC MICRO-CANTILEVER FILTERS FOR APPLICATIONS IN AUDITORY PROSTHESES

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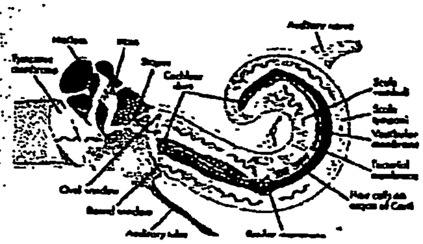
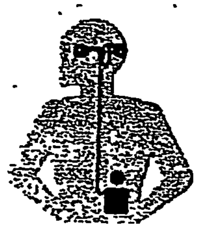
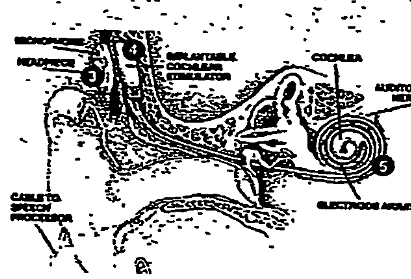
Normal Ear



Sound enters through the outer ear canal and the middle ear to the inner ear, and causes a fluidic traveling wave inside the cochlea. When the hair cells located on the basilar membrane sense the vibration, they generate electrical impulses which travel from the auditory nerves to the brain.

Current Cochlear Implant Technology





Sound waves are received by the microphone (1). The signal from the microphone is sent to the speech processor (2). The speech processor translates sound into an electronic code. The electronic code is sent to the transmitter coil (3). The transmitter coil transmits the signal through the intact skin into the implant (4). The implant package decodes the signal and sends a pattern of electrical pulses to the electrodes (5) in the cochlea, which stimulate the auditory nerves directly.

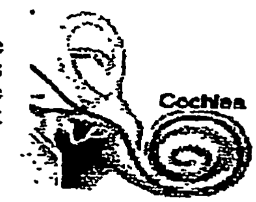
Drawbacks

- *High power consumption*
- *Long processing time*
- *Few processing channels*
- *Large size (body-worn devices)*

Proposed Technology

The keys at right side of the piano resonate at high frequencies while those at left side resonate at low frequencies.

The basilar membrane at the base of the cochlea resonates at high frequencies while that at the apex resonates at low frequencies.

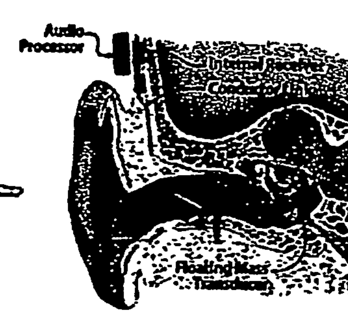


Piano = Digital Cochlea ? !

Make a bionic cochlea and digital hearing aid

With the MEMS technology, the microphone (1), speech processor (2), transmitter coil (3), and implant (4) can be integrated in one chip and inserted in the ear. Don't need body-worn devices.

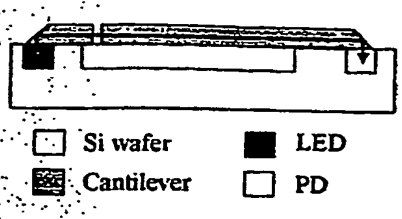
Make a "MICRO-PIANO" and put into the ear. The "micro-piano" can obtain the sound spectra due to the keys' filtering. Each key's output can be converted to electrical pulse to stimulate the auditory nerve located at the part of the basilar membrane that has the same resonance frequency as the key.



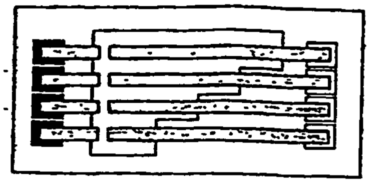
Current Work

Design

Structure



Cross section



Top view

Cantilever Material

Silicon ☒

Silicon is a stiff, high Young's modulus material. It has much different performance from the natural organic material that compose the basilar membrane.

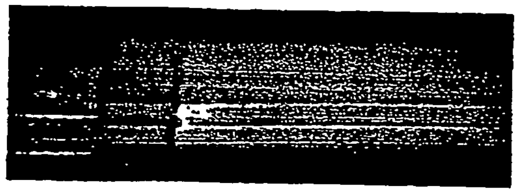
Polymer ☑

Polymer has a low Young's modulus and is similar to natural organic material. The polymeric cantilevers have the same performance as the basilar membrane.

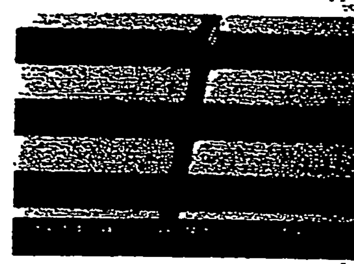
Operation Principle

The light comes out from the light emitting diode (LED) and goes through the cantilever, which is also an optical waveguide, to the photo diode (PD). When the sound wave vibrates the cantilever, the light is modulated by the cantilever. The PD output signal is an electrical signal that has the same frequency as the cantilever resonant frequency. The different cantilevers have different lengths and different resonant frequencies. The output of the PD array is a sound spectra that is the same as a digital signal processing (DSP) output.

Device

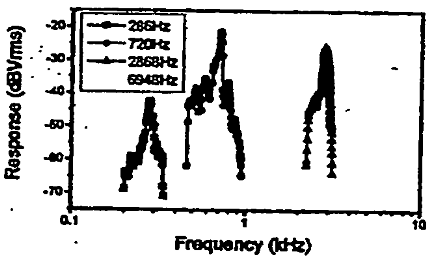


The released polymeric cantilever filters array is made of an epoxy with a Young's modulus of 4.4 GPa. The cantilevers' width is 100 μm, thickness is 50 μm, and length is from 1.5 to 7.4 mm.

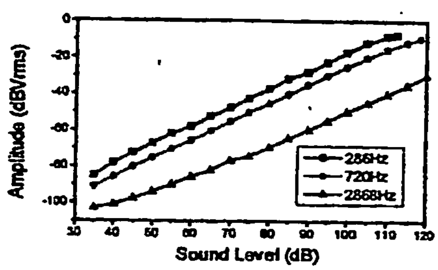


The 20 μm gap and smooth sidewall ensure the good coupling and low loss of light.

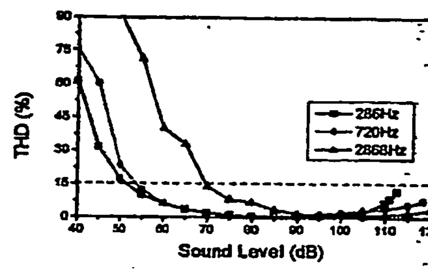
Testing Results



The frequency response curves of the polymeric cantilever filters. These cantilever filters have the Q_{10} values at 9.38, 10.11, 11.56, and 14.01 for resonant frequencies at 286, 720, 2868, and 6948 Hz, respectively. These values are similar to that obtained with direct measurement of the basilar membrane vibration in a normal mammalian cochlea.



The input/output functions of the polymeric cantilever filters responses to tones. They have a linear dynamic range for sound inputs between 35 and 115 dB SPL. The cantilever with the lowest resonant frequency has the largest amplitude in the same input sound level.



The total harmonic distortions (THD) of the polymeric cantilever filters. The THD are less than 15% throughout most of the dynamic range. The cantilever with resonant frequency of 2868Hz has high THD in low sound level. That means the 50 μm thickness is too thick for those cantilever with high resonant frequency. We can reduce their thickness to decrease their THD.

Summary

* Passive operation, low power consumption.
* Mechanical filtering, short processing time.
* MEMS technology, small size and large number of cantilevers.
* Large number of channels, high frequency resolution.
* Polymer material, the same performance as the basilar membrane.
* Optical detection, high sensitivity and free of electromagnetic interference.
* Can be used for both hearing aids and cochlear implants.